University at Buffalo
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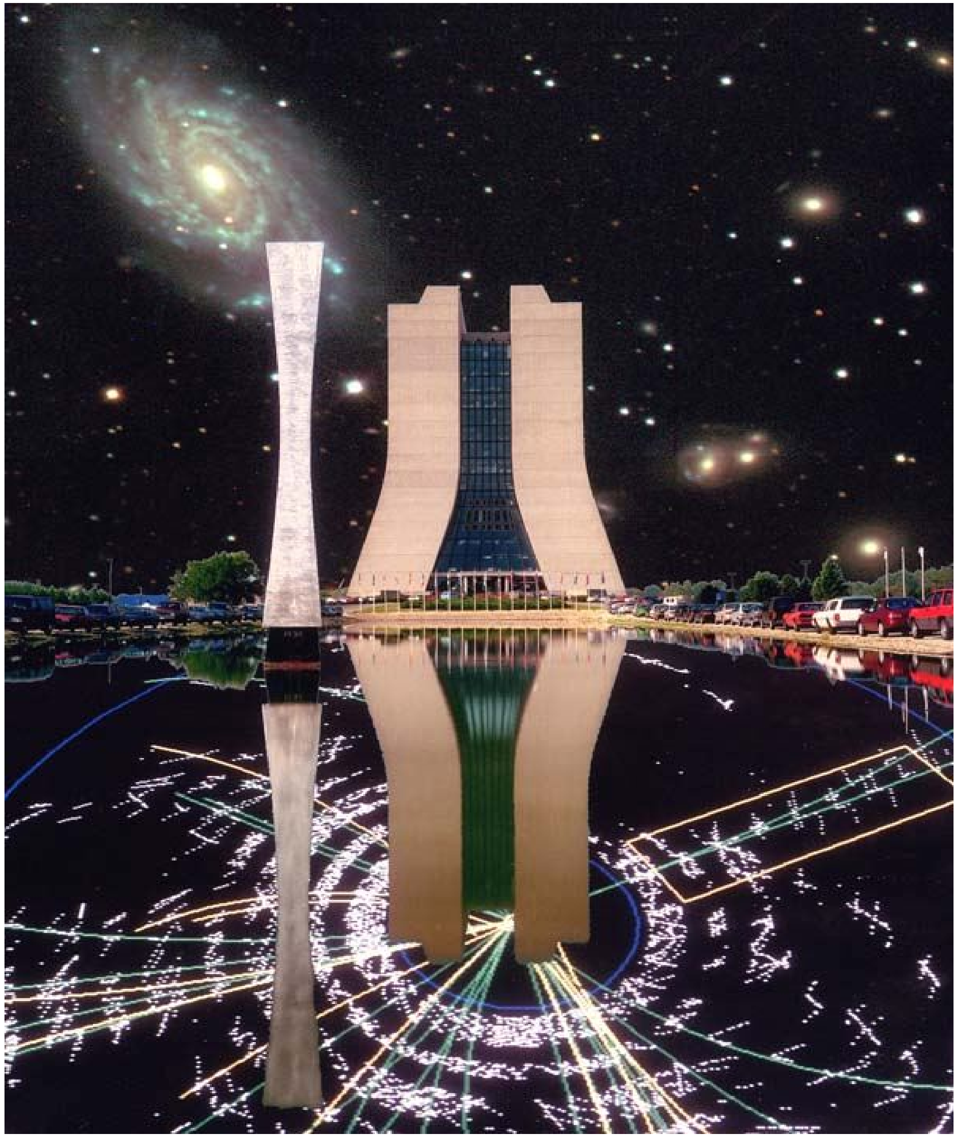


Isolated Photon Cross Section at DØ

DIS 2006
Tsukuba JAPAN

Ashish Kumar
State Univ of New York at Buffalo

On behalf of the DØ Collaboration

Outline

- DØ expt at Fermilab Tevatron
- Motivation
- Analysis strategy
- Cross section results
- Comparison with theory
- Summary

new

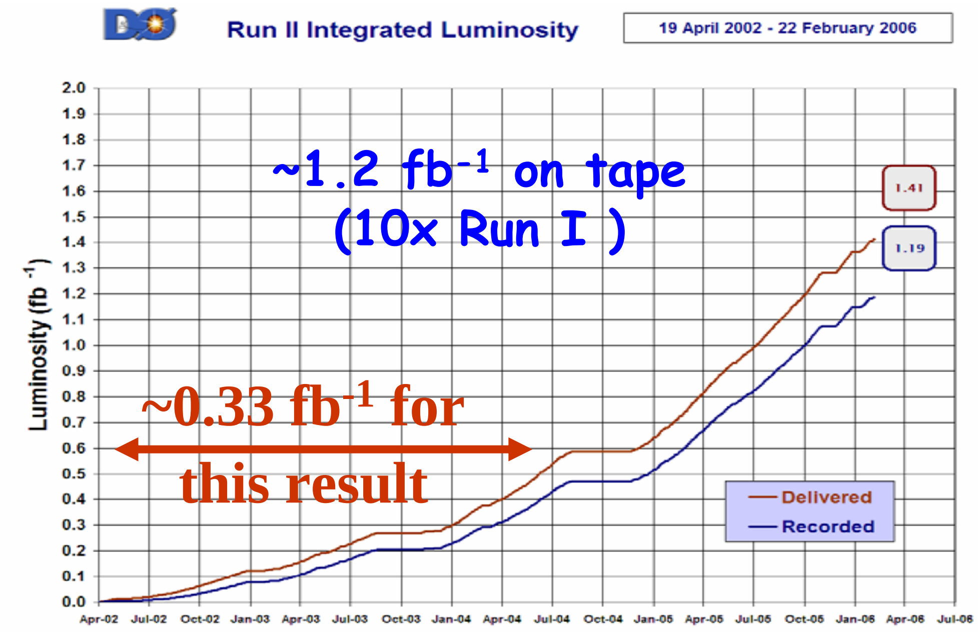
hep-ex/0511045

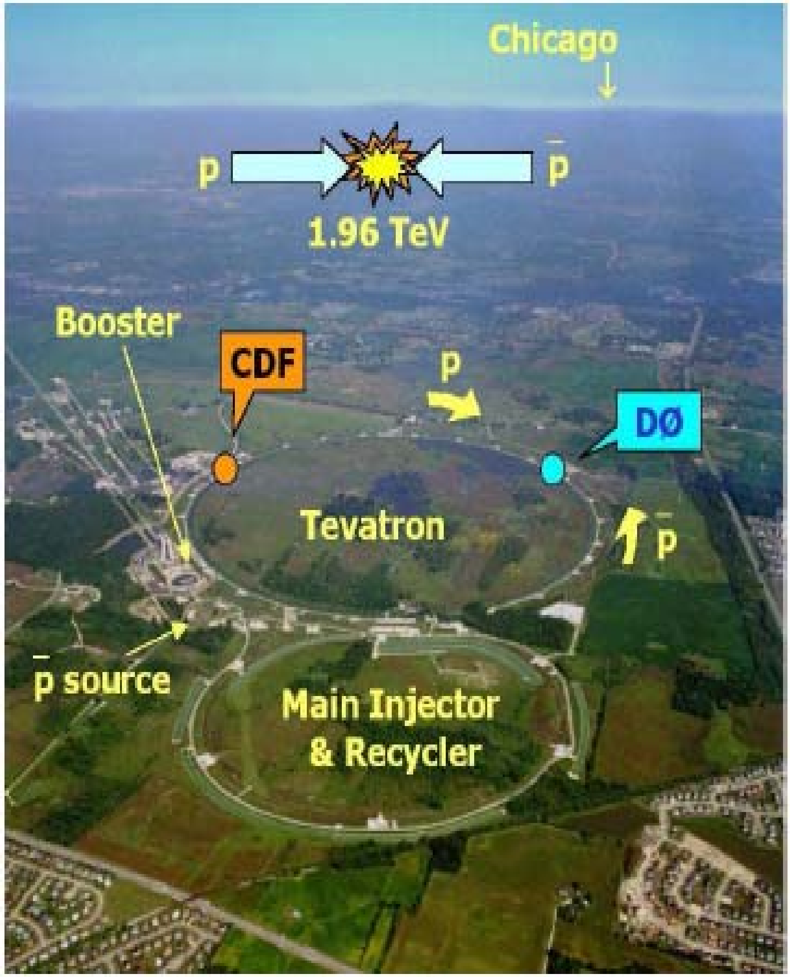
Accepted by Phys.Lett. B

Tevatron $p\bar{p}$-collider

Run II (March 2001→) $\sqrt{s}$ = 1.96 TeV
- 36x36 bunches colliding per 396 ns
- 2-3 interactions/crossing

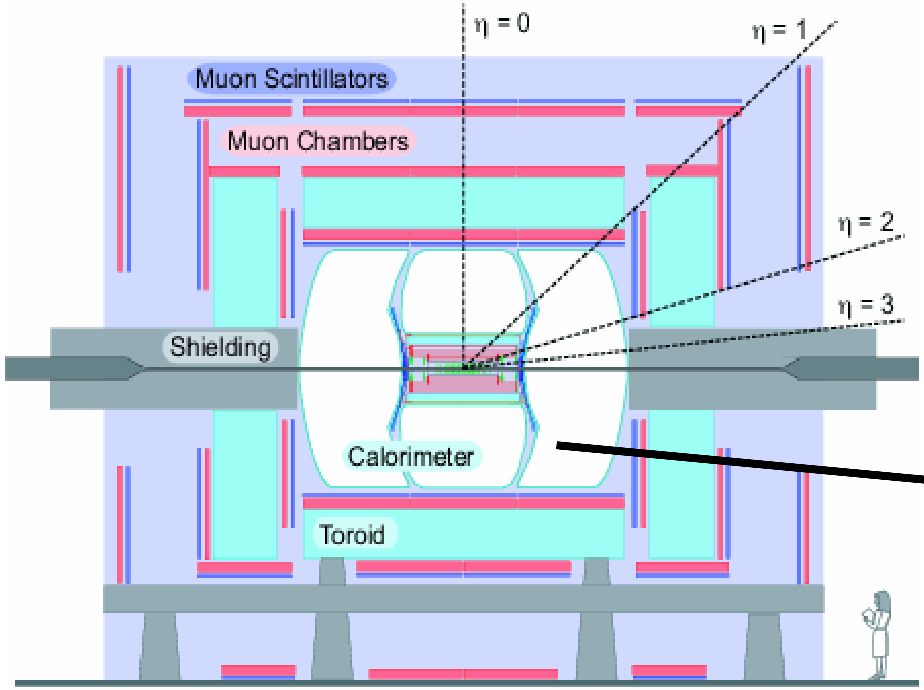
Excellent Tevatron performance!
- Peak $\mathcal{L}$: 1.72E32 $cm^{-2}s^{-1}$ — record high
- $\int \mathcal{L}\, dt$: 27 pb^{-1} /week
- **Delivered >1.4 fb^{-1}**
- Goal : 8 fb^{-1} by 2009

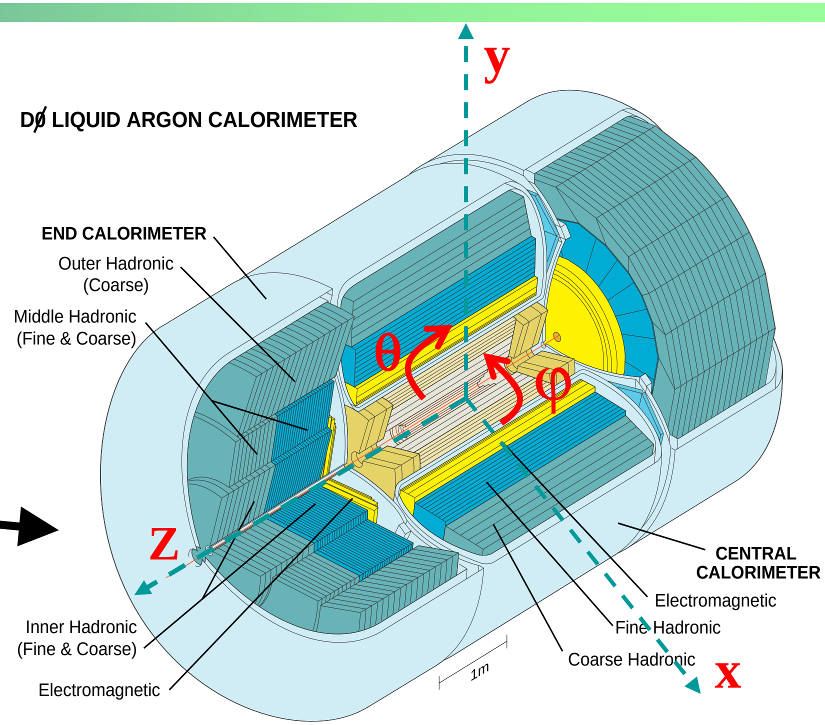




Currently in shutdown
DØ Silicon & Trigger upgrades

The DØ Detector





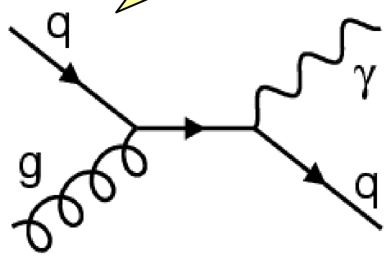
- Inner tracker (silicon mictrostrips and scintillating fibers) inside 2T superconducting solenoid : |η|<2.5
  ⇒**precise vertexing and tracking**
- Wire tracking and scintillating muon system: |η|<2
- Three-Level trigger → 50Hz

- Liquid Ar sampling & U absorber
- Hermetic with full coverage (|η|<4.2)
- 4 EM Layers : shower-max EM3
- **Fine transverse segmentation**
  $\Delta\eta \times \Delta\phi$ = 0.1x0.1 (0.05x0.05 in EM3)
- Good energy resolution

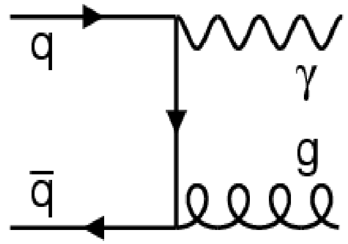
Motivation

Direct photons emerge unaltered from the hard interaction
⇒**direct probe** of the hard scattering dynamics
⇒**clean probe** without complication from fragmentation & systematics associated with jet identification and measurement

Dominant

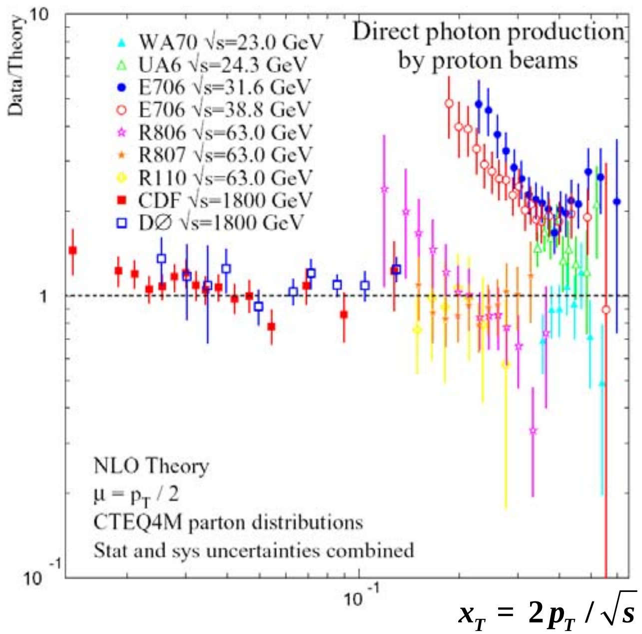


Compton

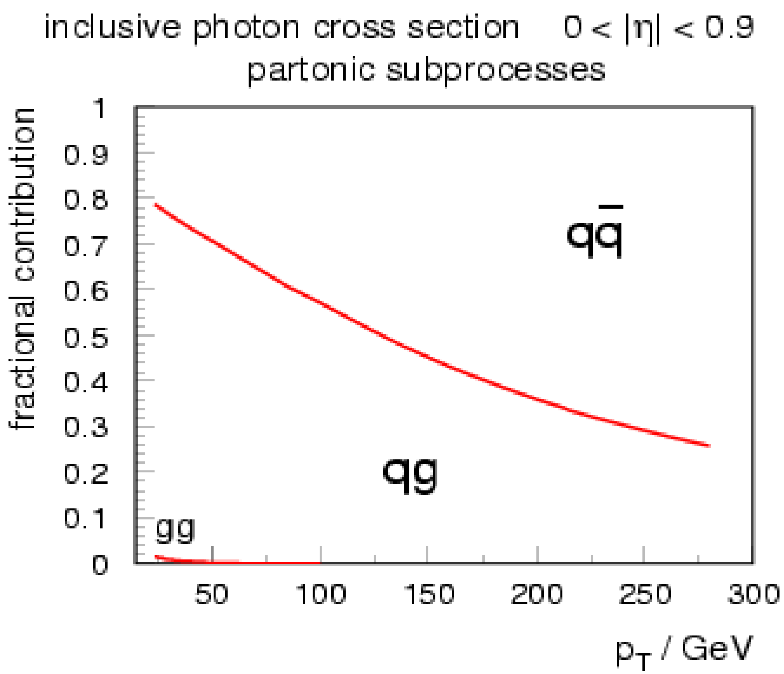


Annihilation

- ❑ **Precision test of pQCD**
- ❑ **Direct information on gluon density** in the proton : gluon involved at LO in contrast to DIS & DY processes
- ❑ Test of soft gluon resummation, models of gluon radiation,..
- ❑ Understanding the QCD production mechanisms of photons is prerequisite to searches for new physics.



Direct Photon Production



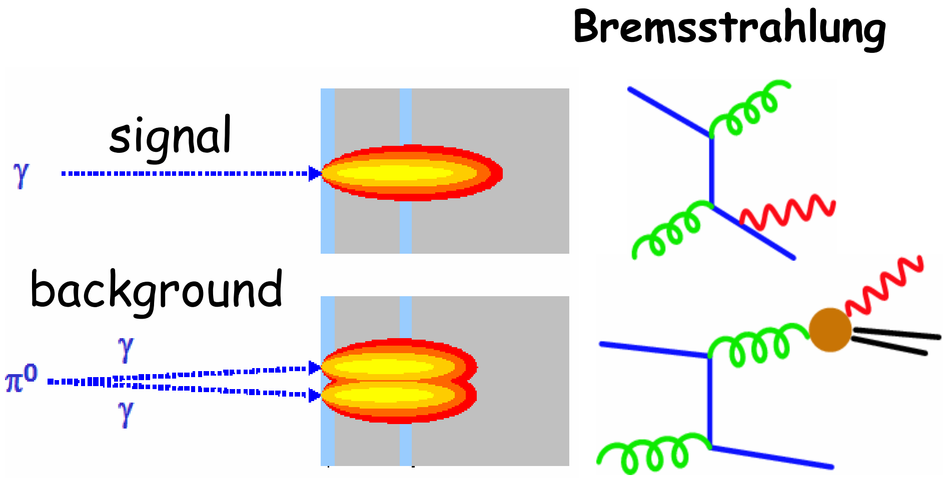
Primarily produced by $qg \rightarrow \gamma q$ for $p_T^{\gamma} < 150$ GeV

$\Rightarrow$precision test of QCD over much **wider p_T^{γ} range** than Run I .

$\Rightarrow$probe $G(x,Q^2)$ with large Q^2 & in wide range: **0.02< x_T <0.25**

Extremely challenging!

$\sigma(\text{jets})/\sigma(\gamma) \approx 10^3 \Rightarrow$ **severe background** from jet fragmenting into a leading π^0 (or η), particularly at small p_T^{γ}

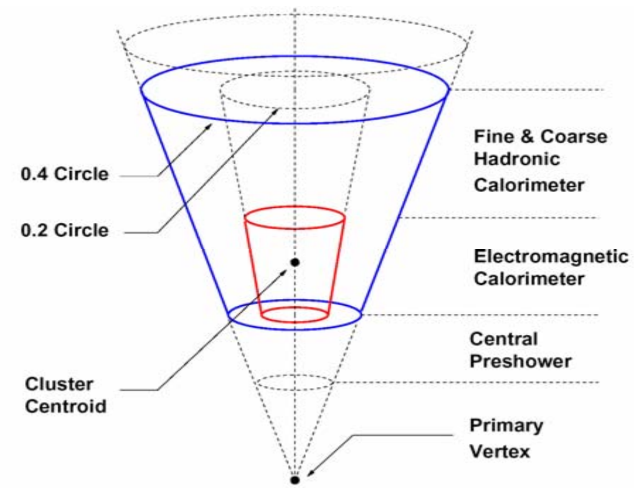


Small background from electroweak processes (mainly W) at high p_T^{γ}

Photon Identification

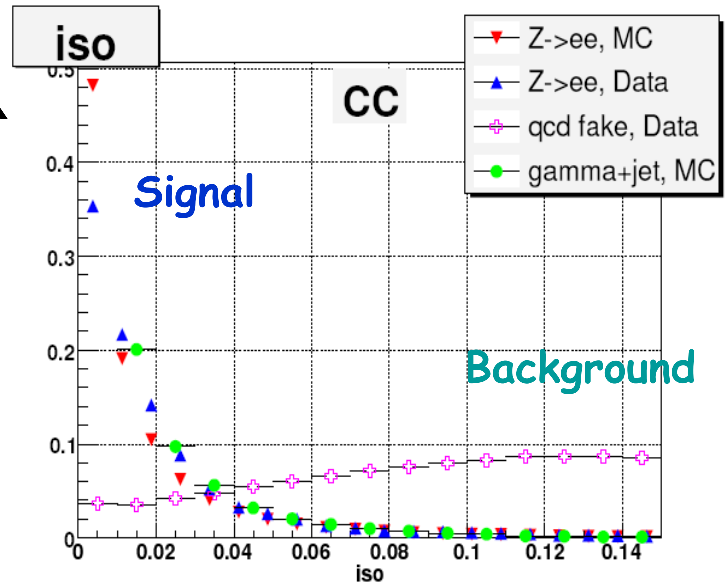
Reconstruct EM objects from energy clusters in calorimeter by cone algorithm

$$E_T^{cluster} = \sum_{R \equiv \sqrt{\Delta\eta^2 + \Delta\varphi^2} \leq 0.4} E_T^{towers}$$



Require :

- >**95%** of energy in EM layers
- **Isolation** : $(E_{total}^{R=0.4} - E_{EM}^{R=0.2}) < 0.1 E_{EM}^{R=0.2}$
- **Veto track(s)** around EM cluster
- Shower profile compatible with photon



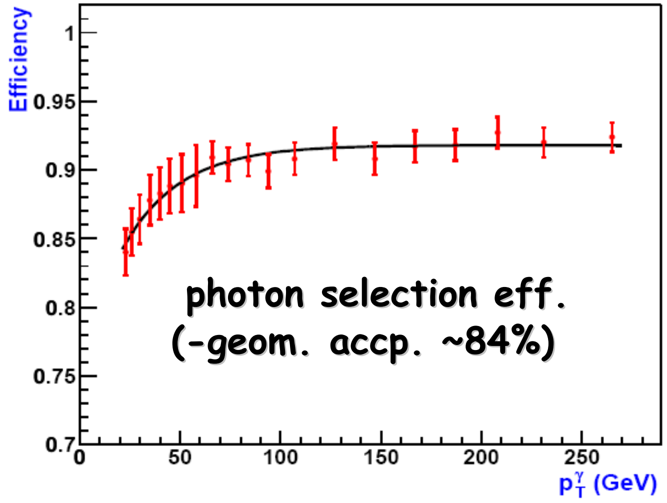
⇒Suppress most of the jet background except when single π^0 or η carries most of the jet's energy : significant amount due to large jet cross section

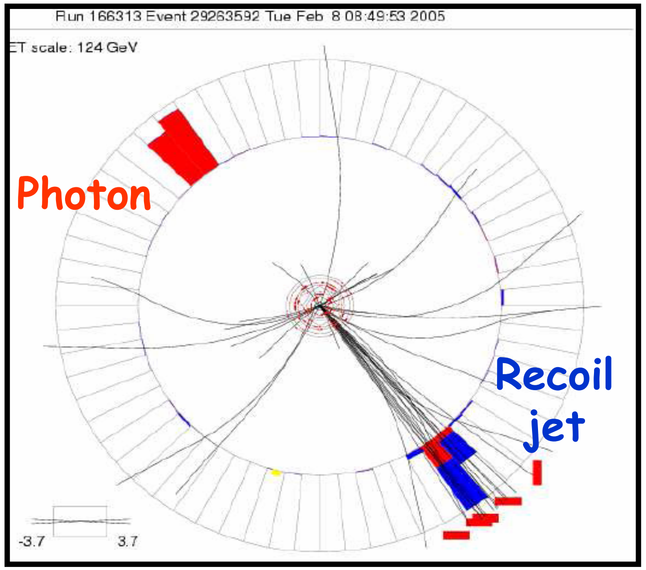
Event Selection

- Single high p_T EM triggers
- Vertex: $|z| < 50$ cm, ≥ 3 tracks
- $p_T^{\gamma} > 23$ GeV
- $|\eta^{\gamma}| < 0.9$
- Small missing E_T ($\not{E}_T/p_T^{\gamma} < 0.7$) to suppress Ws($\rightarrow e\nu$) and cosmic events.

Selection efficiencies estimated with fully simulated γ^{direct}+jet events $\Rightarrow$corrections derived from comparison of $Z\rightarrow e^+e^-$ data/MC events.

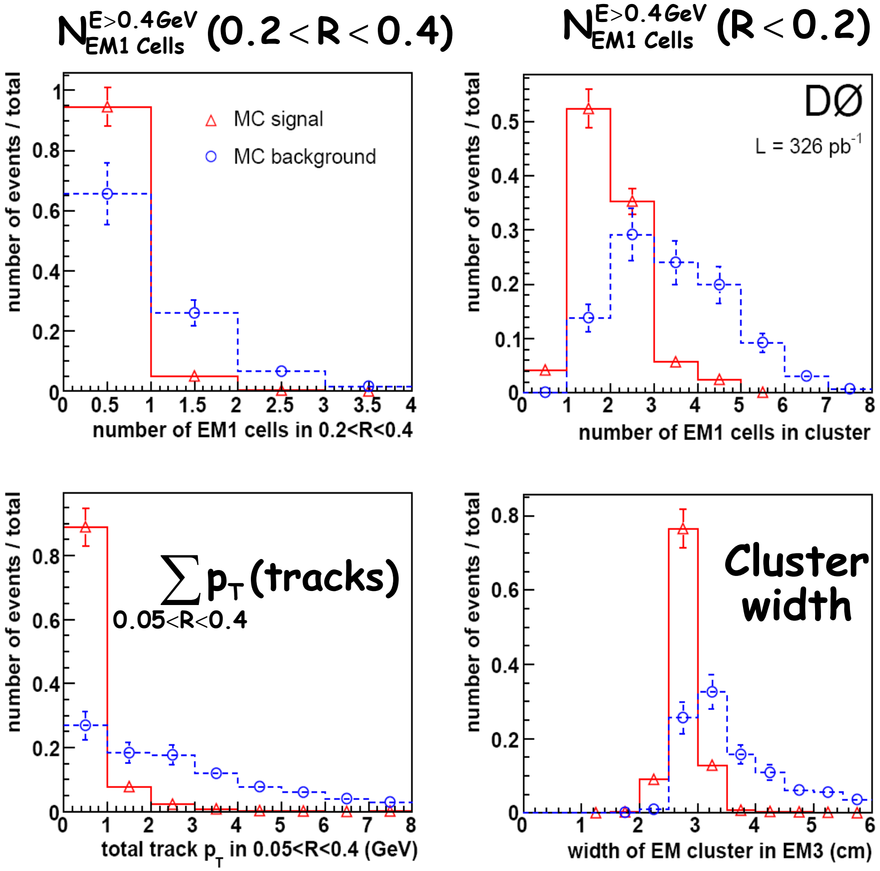
Main background : Highly em-jets with energetic π^0, η, K_s^0, ω. Can be reduced but not entirely removed.



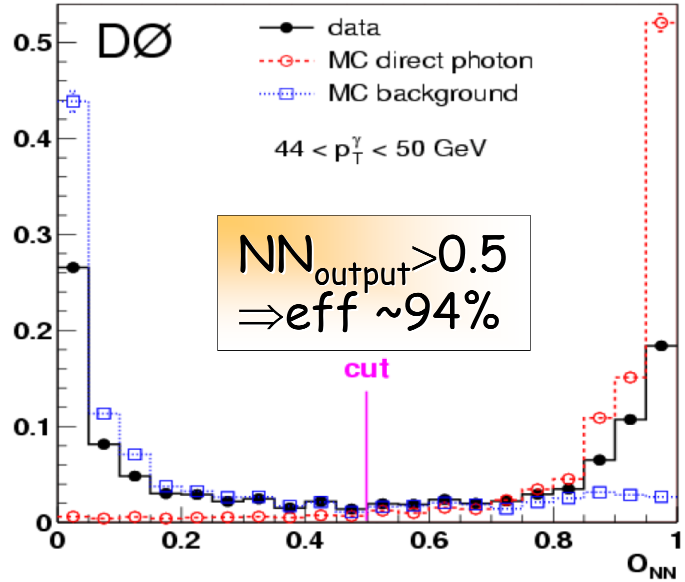


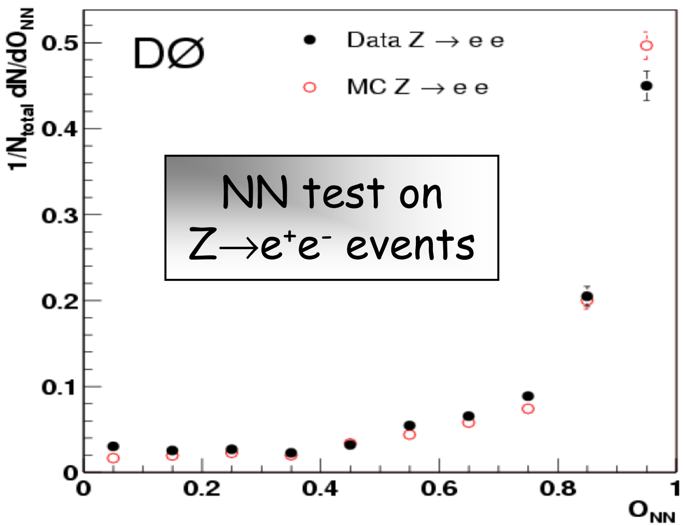
Background Suppression

Design a neural network (NN)



NN trained to discriminate between direct photons and em-jets.





Photon Purity

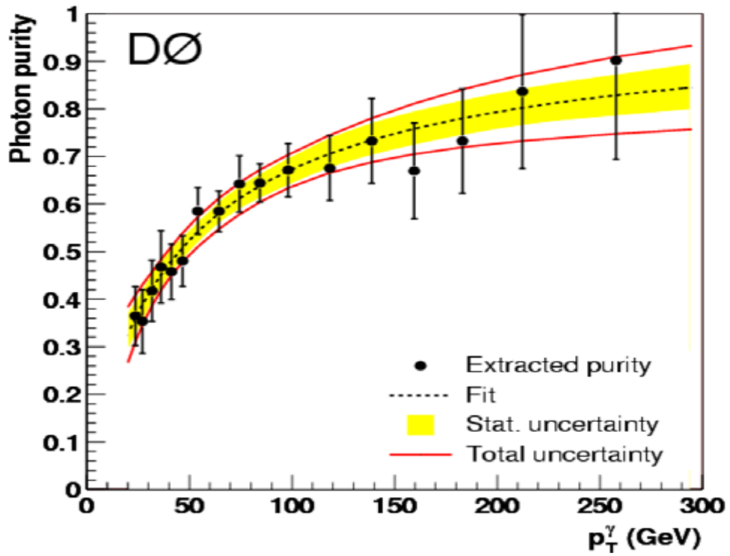
After NN selection : 2.7×10^6 photon candidates : 17 p_T^γ bins

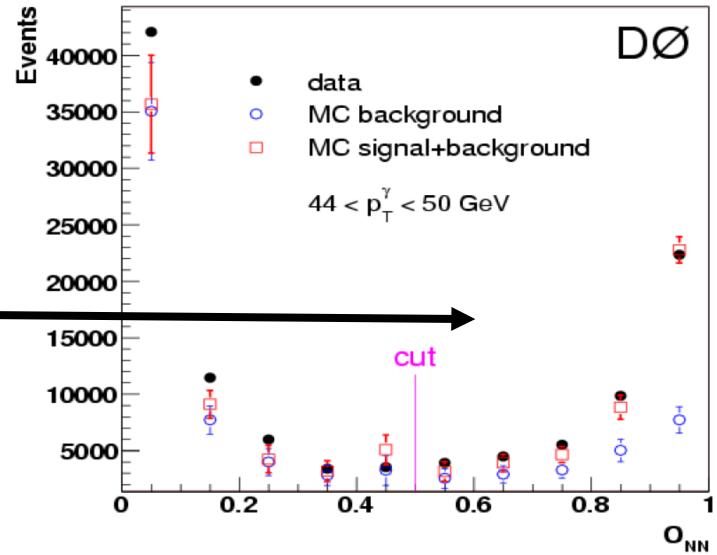
Photon purity determined from fitting NN output in data to predicted NN outputs for signal and background.

⇒statistical uncertainty dominated by MC statistics (em-jet) at low p_T^γ and data statistics at high p_T^γ.

⇒systematic uncertainty from fitting and fragmentation model in Pythia.

Data well described by the sum of MC signal + background samples, especially for events with $NN_{output}>0.5$.





Isolated Photon Cross Section

2.7×10^6 γ candidates : $23 < p_T^\gamma < 300$ GeV

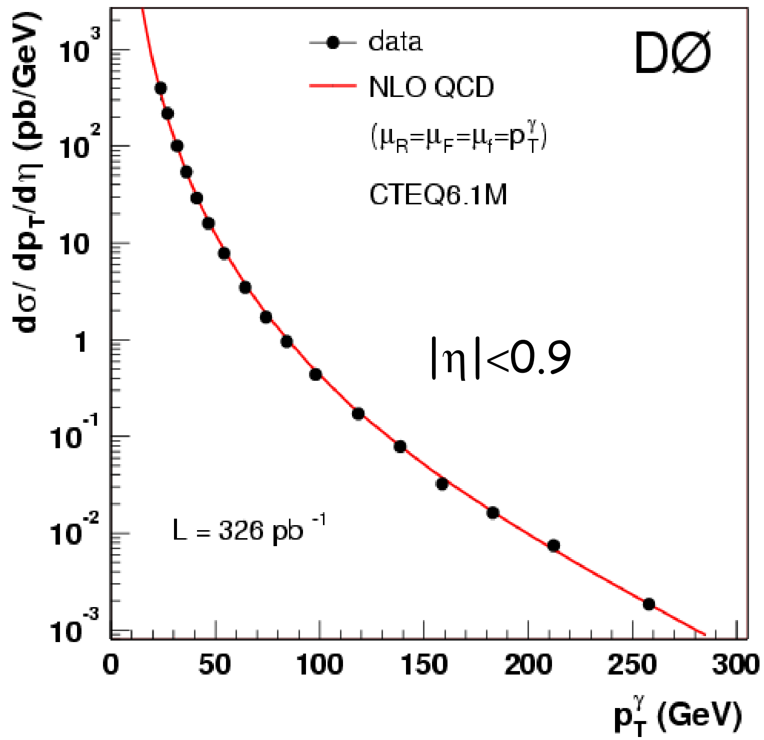
Correction for finite detector resolution. p_T^γ corrected for shift in energy scale.

Results shown with statistical $\oplus$ systematic uncertainties.

Theory : NLO pQCD calculation from JETPHOX (P. Aurenche et. al.) using CTEQ6.1M PDFs & BFG FFs.

NLO calculation by Vogelsang et. Al. based on small- cone approx. and using GRV FFs agree within 4%.

$$\frac{d^2\sigma}{dp_T d\eta} = \frac{N\,\mathcal{P}\,U}{L\,\Delta p_T^\gamma \Delta\eta\, A\epsilon}$$



Theoretical predictions consistent with measured cross-section.

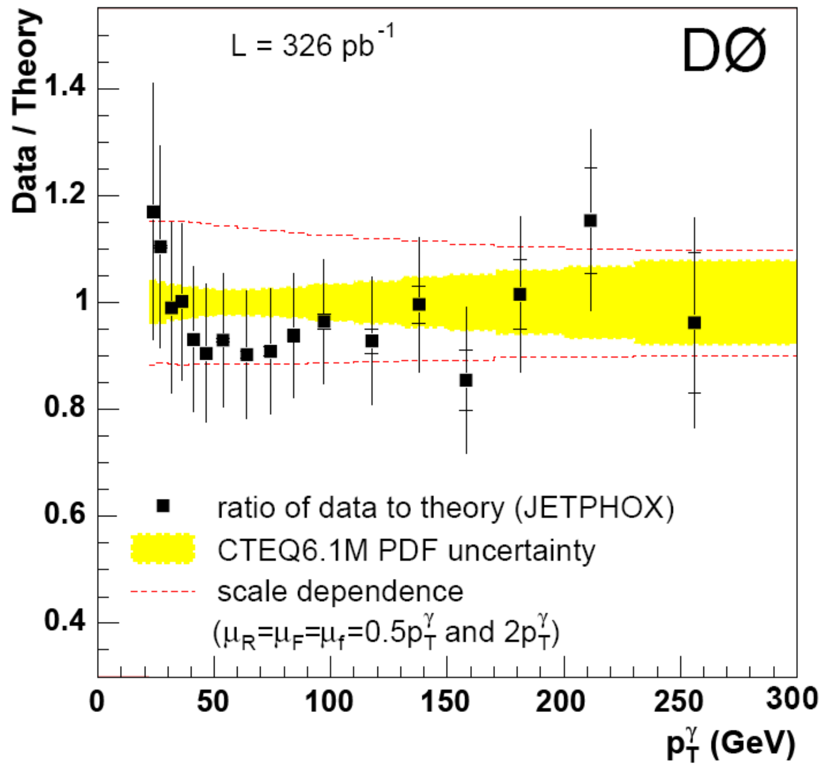
Data vs Theory

Good agreement within uncertainties, in the whole p_T^γ range.

- Uncertainty from choice of PDFs (MRST2004/Alekhin2002) < 7%.
- Variation in calculations for 50% change in isolation requirement and hadronic fraction in the cone <3%

Shape diff. at low p_T^γ : interpretation difficult due to large theoretical scale uncertainty and exp. syst. uncertainty.

NNLO calculations should reduce scale dependence. Calculations enhanced for soft-gluon contributions should provide better descriptions of data at low p_T^γ.



Measurement uncertainties
Statistical : 0.1% - 13.2%
Systematic : 13% - 25%
-- mainly from purity estimation

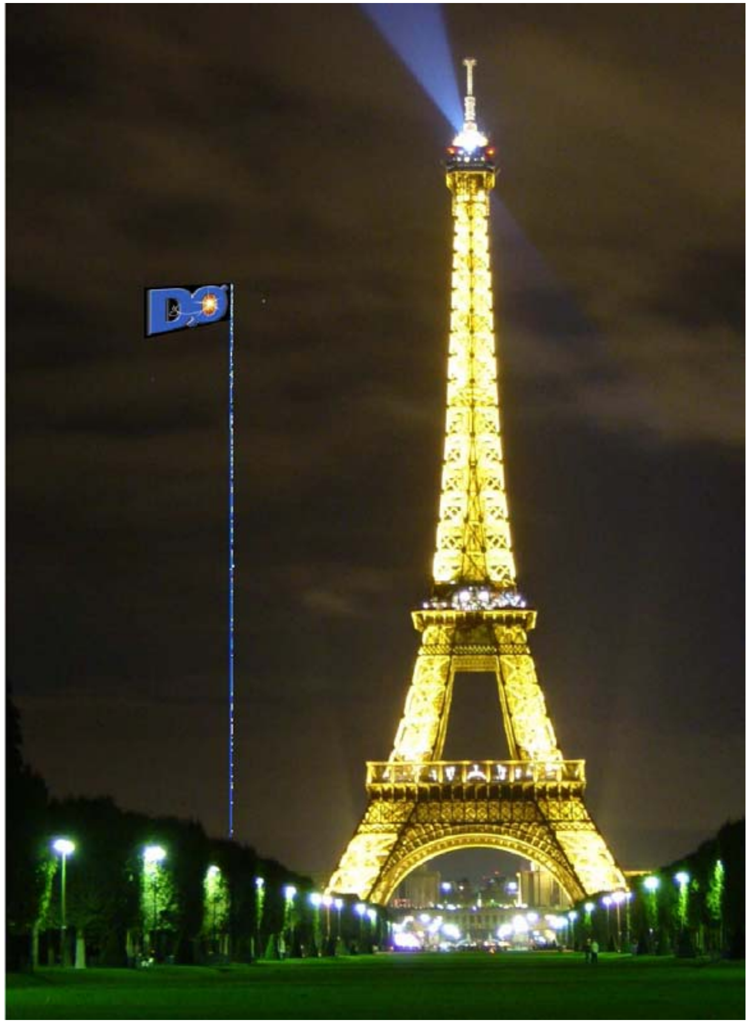
Summary

Direct photon production is an ideal testing ground for QCD predictions and constraining PDFs.

DØ has measured inclusive cross section of isolated photons in central region ($|\eta|<0.9$) and in the widest p_T^γ domain ever covered ($23 < p_T^\gamma < 300$ GeV). Results from the NLO pQCD agree with the measurement within uncertainties.

Exciting work in progress with ~1 fb^{-1} data. Also on other fronts : $\gamma\gamma$, γ+jet, γ +heavy flavor jet ..

So stay tuned!



Stack of disks with DØ data will soon eclipse Eiffel Tower.

Backup

Photon Energy Scale

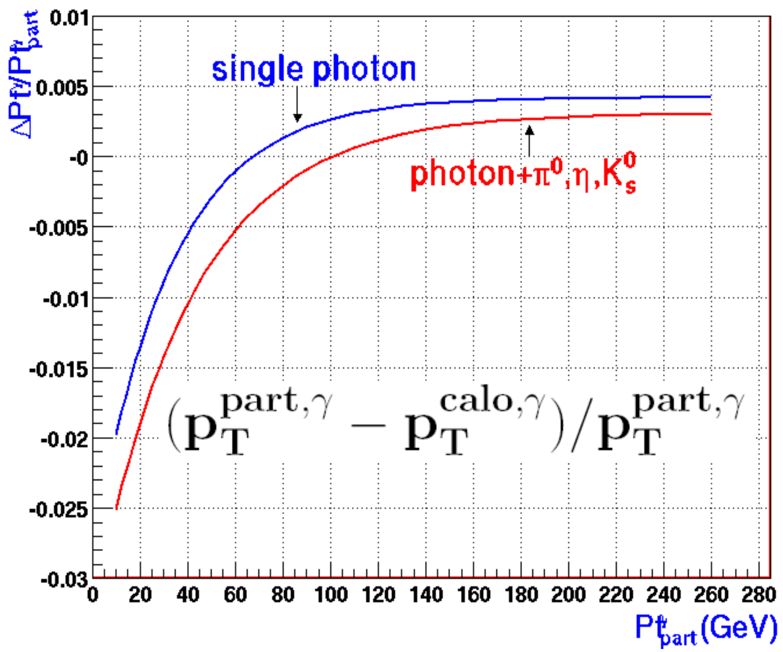
Photons lose noticeably less energy in the material upstream of calorimeter than electrons (used for energy calibration)

⇒systematic over-correction in the energy scale for photons which would yield shift in the measured cross section.

⇒need to correct p_T^γ

Neutral mesons component yield photons of smaller energy ⇒ additional shift of the measured p_T^γ.

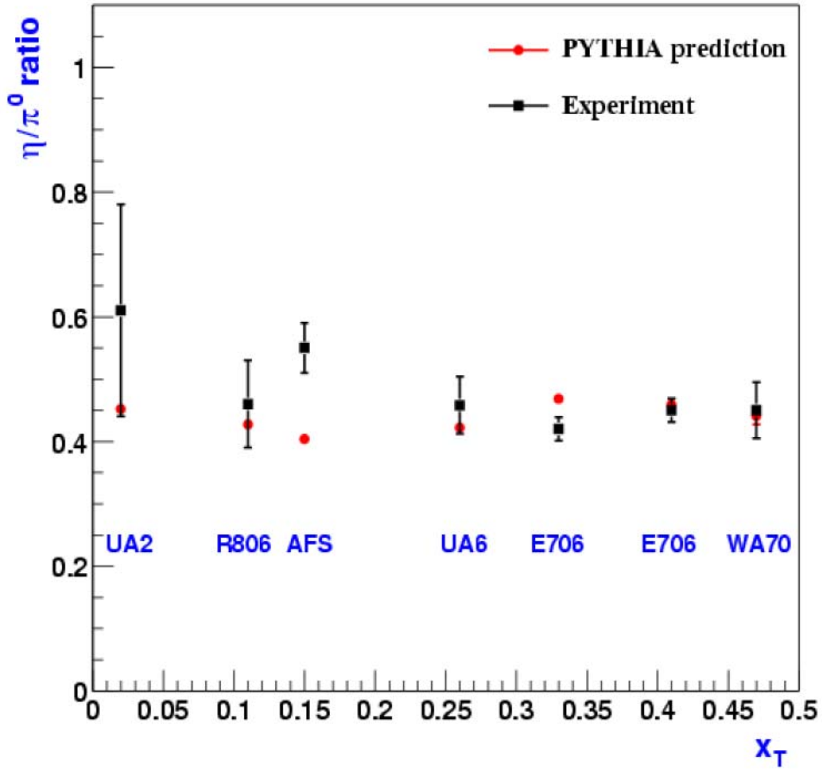
Use γ+jet and em-jet simulated events to determine shift between true and reconstructed p_T^γ ⇒1.9% at 20 GeV, 1% at 40 GeV and <0.3% above 70 GeV.

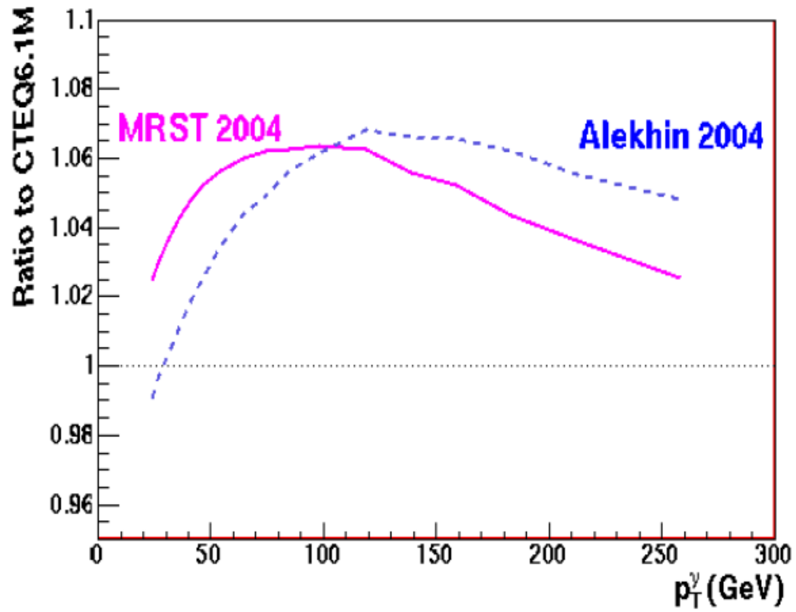


Systematic Uncertainties

Luminosity : 6.5%
Vertex determination : 3.6 - 5.0%
Energy calibration : 9.6 – 5.5%
Fragmentation model : 1.0 – 7.3%
Photon conversions : 3%
Photon purity fit : 6 – 13%

Statistical uncertainties on determination of
Geometric Acceptance : 1.5%
Trigger efficiency : 11 – 1%
Selection efficiency : 5.4 – 3.8%
Unsmearing : 1.5%


PYTHIA prediction
Experiment
η/π^0 ratio
x_T
UA2
R806
AFS
UA6
E706
E706
WA70

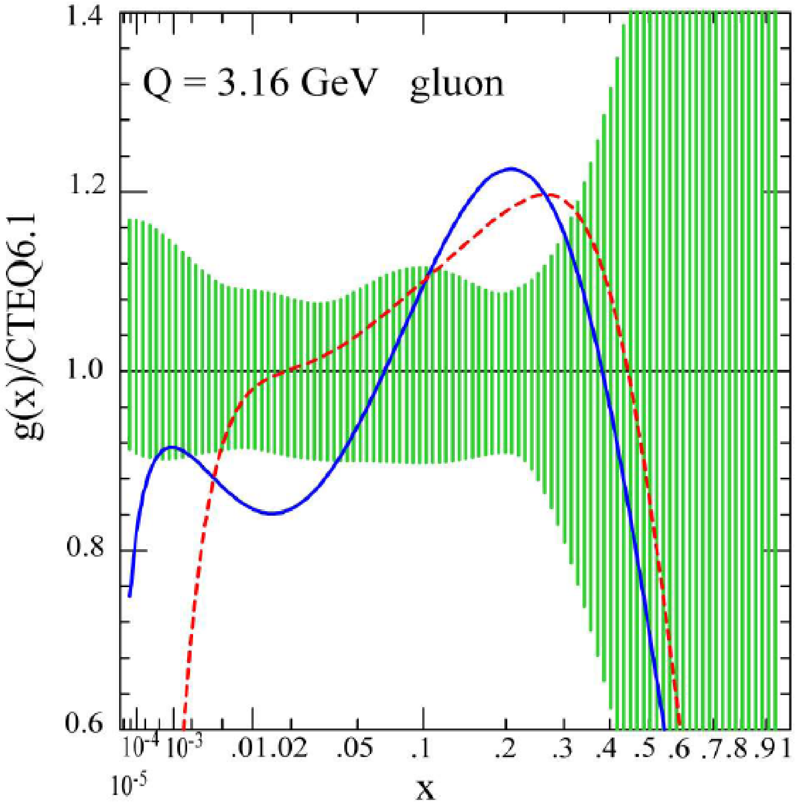

Ratio to CTEQ6.1M
MRST 2004
Alekhin 2004
p_T^γ (GeV)

Gluon distribution uncertainties

Most uncertain of the PDFs. The plot shows current uncertainty of the gluon distribution (due to experimental inputs only) estimated by CTEQ6.

❖ ≈15% for x<0.25 and increases rapidly for larger x.

❖at small x, the theoretical uncertainty (not included here) should increase widening the error band



Isolation Efficiency